ASTM Committee Meeting
E08.07.03 Surface Cracks

E2899 Business

May 6, 2014

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Damage Tolerance Assessment Branch

Agenda

A. Approval of the minutes from November 2013 meeting in Jacksonville, FL

B. Old Business

- Official release of E2899
- Analytical round robin phase II kickoff

C. New Business

- Proposed changes for E2899
- Analytical round robin phase II update
- Tool for Analysis of Surface Cracks (TASC) update

E2899 Release

E2899 Release

- The new surface crack standard, E2899, was officially released by ASTM in October 2013 and is now available for download from the website.

- Will be discussing proposed changes at this meeting.

Designation: E2899 – 13

Standard Test Method for Measurement of Initiation Toughness in Surface Cracks Under Tension and Bending[1]

This standard is issued under the fixed designation E2899; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes the method for testing fatigue-sharpened, semi-elliptically shaped surface cracks in rectangular flat panels subjected to monotonically increasing tension or bending. Tests quantify the crack-tip conditions at initiation of stable crack extension or immediate unstable crack extension.

1.2 This test method applies to the testing of metallic materials not limited by strength, thickness, or toughness. Materials are assumed to be essentially homogeneous and free of residual stress. Tests may be conducted at any appropriate temperature. The effects of environmental factors and sustained or cyclic loads are not addressed in this test method.

1.3 This test method describes all necessary details for the user to test for the initiation of crack extension in surface crack test specimens. Specific requirements and recommendations are provided for test equipment, instrumentation, test specimen design, and test procedures.

1.4 Tests of surface cracked, laboratory-scale specimens as described in this test method may provide a more accurate understanding of full-scale structural performance in the presence of surface cracks. The provided recommendations help to assure test methods and data are applicable to the intended purpose.

1.5 This test method prescribes a consistent methodology for test and analysis of surface cracks for research purposes and to assist in structural assessments. The methods described here utilize a constraint-based framework (**1, 2**)[2] to evaluate the fracture behavior of surface cracks.

NOTE 1—*Constraint-based framework.* In the context of this test method, constraint is used as a descriptor of the three-dimensional stress and strain fields in the near vicinity of the crack tip, where material contractions due the Poisson effect may be suppressed and therefore produce an elevated, tensile stress state (**3, 4**). (See further discussions in Terminology and Significance and Use.) When a parameter describing this stress state, or constraint, is used with the standard measure of crack-tip stress amplitude (K or J), the resulting two-parameter characterization broadens the ability of fracture mechanics to accurately predict the response of a crack under a wider range of loading. The two-parameter methodology produces a more complete description of the crack-tip conditions at the initiation of crack extension. The effects of constraint on measured fracture toughness are material dependent and are governed by the effects of the crack-tip stress-strain state on the micromechanical failure processes specific to the material. Surface crack tests conducted with this test method can help to quantify the material sensitivity to constraint effects and to establish the degree to which the material toughness correlates with a constraint-based fracture characterization.

1.6 This test method provides a quantitative framework to categorize test specimen conditions into one of three regimes: (I) a linear-elastic regime, (II) an elastic-plastic regime, or (III) a field-collapse regime. Based on this categorization, analysis techniques and guidelines are provided to determine an applicable crack-tip parameter for the linear-elastic regime (K or J) or the elastic-plastic regime (J), and an associated constraint parameter. Recommendations are provided to assess the test data in the context of a toughness-constraint locus (**2**). The user is directed to other resources for evaluation of the test specimen in the field-collapse regime when extensive plastic deformation in the specimen eliminates the identifiable crack-front fields of fracture mechanics.

1.7 The specimen design and test procedures described in this test method may be applied to evaluation of surface cracks in welds; however, the methods described in this test method to analyze test measurements may not be applicable. Weld fracture tests generally have complicating features beyond the scope of data analysis in this test method, including the effects of residual stress, microstructural variability, and non-uniform strength. These effects will influence test results and must be considered in the interpretation of measured quantities.

1.8 This test method is not intended for testing surface cracks in steel in the cleavage regime. Such tests are outside the scope of this test method. A methodology for evaluation of cleavage fracture toughness in ferritic steels over the ductile-to-brittle region using C(T) and SE(B) specimens can be found in ASTM E1921.

1.9 *Units*—The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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[1] This test method is under the jurisdiction of ASTM Committee E08 on Fatigue and Fracture and is the direct responsibility of Subcommittee E08.07 on Fracture Mechanics.

Current edition approved July 1, 2013. Published October 2013. DOI: 10.1520/E2899-13.

[2] The boldface numbers in parentheses refer to the list of references at the end of this test method.

Change to elliptical shape requirements

8.4.2 *Precrack Shape Evaluation*—The precrack shall be evaluated for semi-elliptical shape. If the maximum $2c$ dimension ($2c_{max}$) occurs at the surface, then $2c_0 \equiv 2c_{surf}$. If $2c_{max}$ did not occur at the free surface, evaluate as follows. If $2c_{max} \geq 1.05 \times 2c_{surf}$ then the crack is not sufficiently elliptical; otherwise, if $2c_{max} \leq 1.05 \times 2c_{surf}$ and $a_{2c\text{-}max} \leq 0.1 \times a_0$, then $2c_0 \equiv 2c_{max}$. Calculate values of $2c_{ellipse}$ by substituting $a_0/2$ and a_ϕ for $a_{measured}$ in the relation below. The precrack is considered sufficiently elliptical if the measured values ($2c_{a/2}$ and $2c_\phi$) compare within 5% of their respective $2c_{ellipse}$ values:

$$2c_{ellipse} = 2c_0 \sqrt{1 - \frac{a^2_{measured}}{a^2_0}} \tag{5}$$

If the precrack is not sufficiently elliptical per these criteria, then the test cannot be evaluated using the analytical relations provided in this test method.

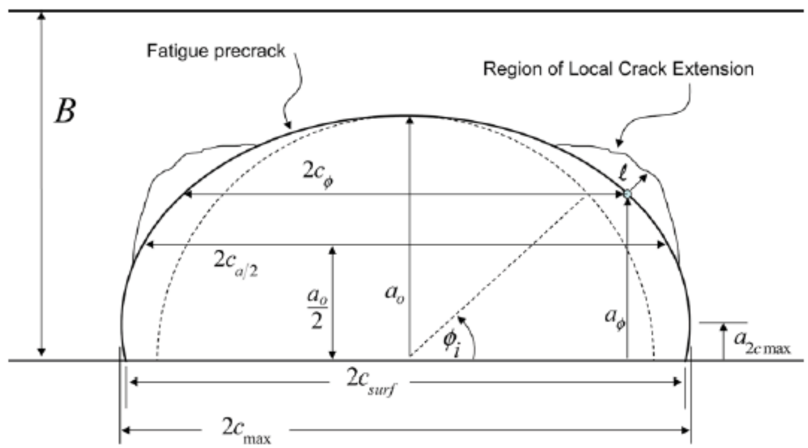

FIG. 7 Required Measurements of Precrack Dimensions and Crack Extension

E2899 Proposed Changes

Change to EPFM regime description

9.2.2.2 Evaluate both specimen characteristic lengths, $r_{\phi a}$ and $r_{\phi b}$, against their respective elastic-plastic regime limits. Both evaluations must be true for valid use of the elastic-plastic regime.

(1) The amount of crack-tip opening displacement must be a small fraction of the crack size such that $r_{\phi a} \geq C_{Ja}(J_{\phi}/\sigma_{YS})$ where:

$$C_{Ja} = 15 \quad (8)$$

(2) The remaining ligament must have a sufficient size relative to the deformation such that $r_{\phi b} \geq C_{Jb}(J_{\phi}/\sigma_{YS})$ where:

$$C_{Jb} = \frac{1}{20}\frac{E}{\sigma_{YS}} + 50 \quad (9)$$

9.2.2.3 If $r_{\phi a} \geq C_{Ja}(J_{\phi}/\sigma_{YS})$ and $r_{\phi b} \geq C_{Jb}(J_{\phi}/\sigma_{YS})$ then assessment in the elastic-plastic regime applies and J_{ϕ} is valid (see regions B and D in Fig. 8). Otherwise, a transferrable J_{ϕ} value cannot be reported per this test method due to collapse of the crack-front strain and stress fields. In this case, assess the sample for field-collapse conditions per section 9.2.3.

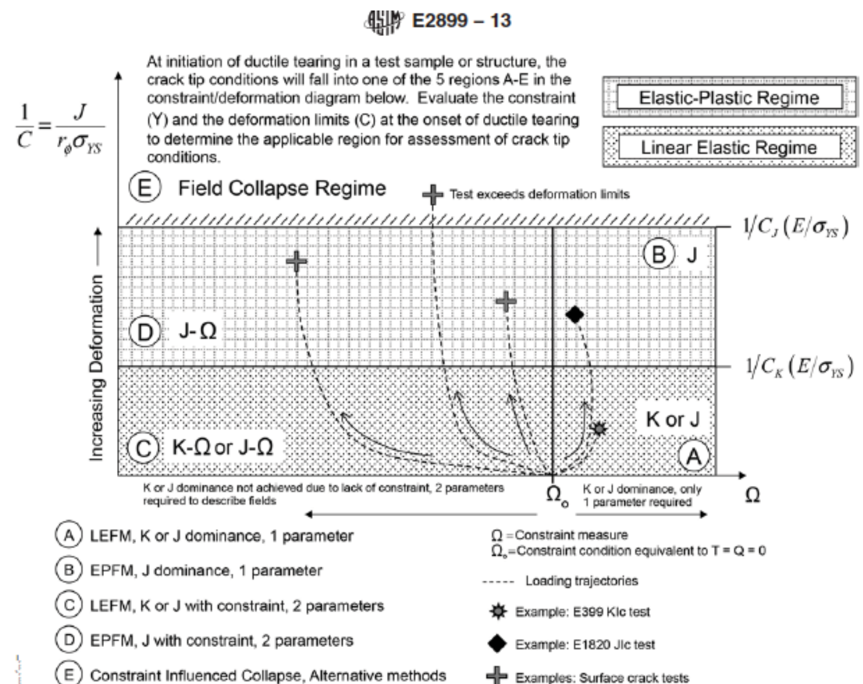

FIG. 8 Assessment of Crack Front Conditions

E2899 Proposed Changes

Editorial changes

TABLE A2.1 Normalized *T*-stress Values for Surface Crack in Tension with *a/c* = 0.1

Crack Front Angle, ϕ [deg]	Normalized *T*-stess (T/σ)				
	a/B = 0.1	a/B = 0.2	a/B = 0.4	a/B = 0.6	a/B = 0.8
5	-0.395	-0.404	-0.439	-0.489	-0.523
10	-0.471	-0.486	-0.532	-0.588	-0.614
15	-0.489	-0.500	-0.548	-0.576	-0.615
20	-0.496	-0.490	-0.547	-0.567	-0.568
25	-0.508	-0.498	-0.555	-0.576	-0.519
30	-0.519	-0.520	-0.566	-0.571	-0.480
35	-0.523	-0.528	-0.566	-0.557	-0.438
40	-0.524	-0.526	-0.566	-0.546	-0.394
45	-0.526	-0.526	-0.567	-0.535	-0.354
50	-0.528	-0.527	-0.568	-0.524	-0.316
55	-0.529	-0.528	-0.570	-0.513	-0.281
60	-0.530	-0.529	-0.571	-0.504	-0.251
65	-0.531	-0.531	-0.572	-0.494	-0.229
70	-0.532	-0.532	-0.574	-0.486	-0.215
75	-0.532	-0.532	-0.574	-0.479	-0.209
80	-0.532	-0.533	-0.575	-0.473	-0.208
85	-0.533	-0.534	-0.575	-0.470	-0.210
90	-0.533	-0.533	-0.575	-0.469	-0.213

TABLE A2.4 Normalized *T*-stress Values for Surface Crack in Tension with *a/c* = 0.6

Crack Front Angle, ϕ [deg]	Normalized *T*-stess (T/σ)				
	a/B = 0.1	a/B = 0.2	a/B = 0.4	a/B = 0.6	a/B = 0.8
5	-0.603	-0.590	-0.614	-0.615	-0.658
10	-0.495	-0.490	-0.496	-0.493	-0.495
15	-0.471	-0.466	-0.466	-0.449	-0.420
20	-0.464	-0.458	-0.456	-0.426	-0.380
25	-0.463	-0.456	-0.453	-0.416	-0.359
30	-0.467	-0.458	-0.456	-0.416	-0.358
35	-0.472	-0.462	-0.463	-0.423	-0.378
40	-0.477	-0.467	-0.471	-0.437	-0.415
45	-0.483	-0.472	-0.480	-0.455	-0.463
50	-0.489	-0.477	-0.490	-0.477	-0.522
55	-0.494	-0.483	-0.500	-0.502	-0.580
60	-0.499	-0.488	-0.509	-0.526	-0.641
65	-0.503	-0.493	-0.518	-0.550	-0.700
70	-0.506	-0.497	-0.526	-0.573	-0.755
75	-0.508	-0.500	-0.532	-0.592	-0.801
80	-0.510	-0.502	-0.537	-0.606	-0.836
85	-0.511	-0.503	-0.540	-0.615	-0.858
90	-0.511	-0.504	-0.541	-0.618	-0.868

Objectives:

1) Determine the consistency in the interpretation of the test evaluation requirements in E2899.
2) Provide additional information on the analytical consistency of finite element (FE) methods as prescribed in the standard for future revision of the precision and bias statements. An evaluation of interpolated solutions as an alternative to FE will also be requested through use of the recently developed TASC.

To Participate or Ask Questions:

Please email us:

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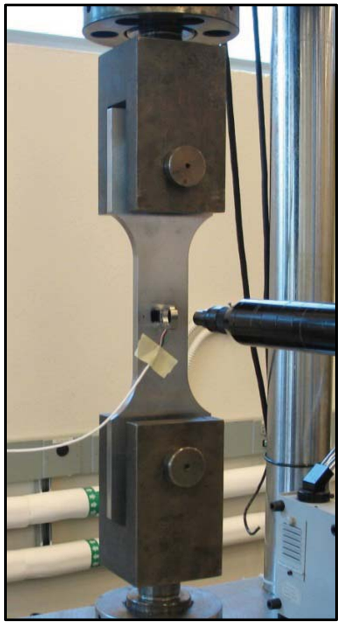
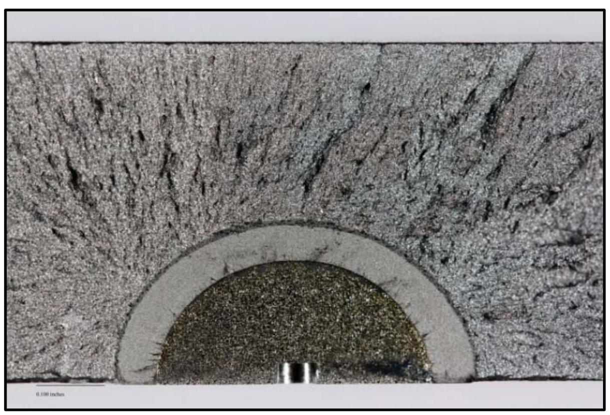
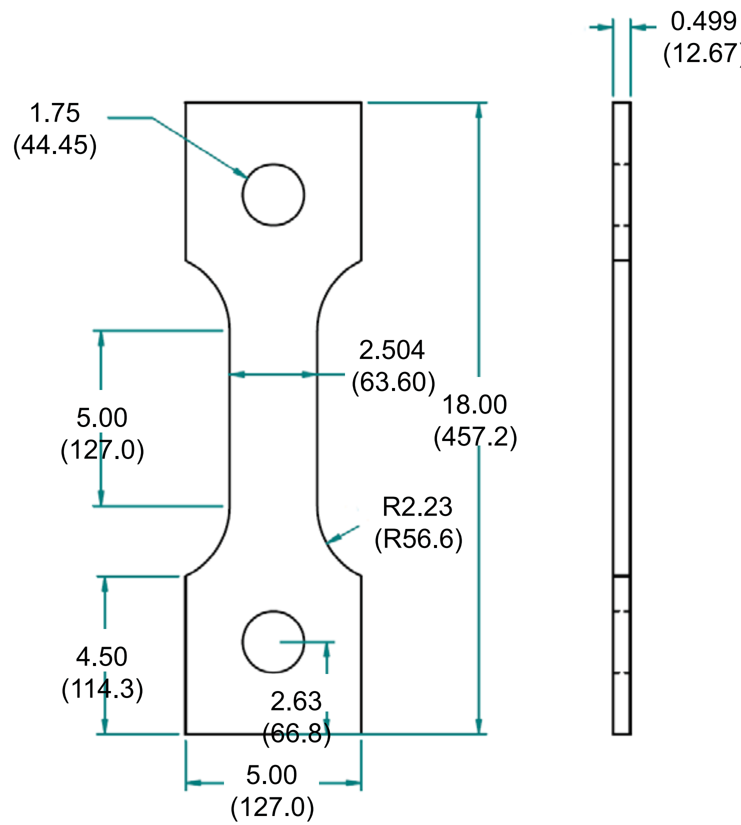
Analytical Round Robin Phase II

RR Phase II based on 4142 steel SC(T) test







Current participants

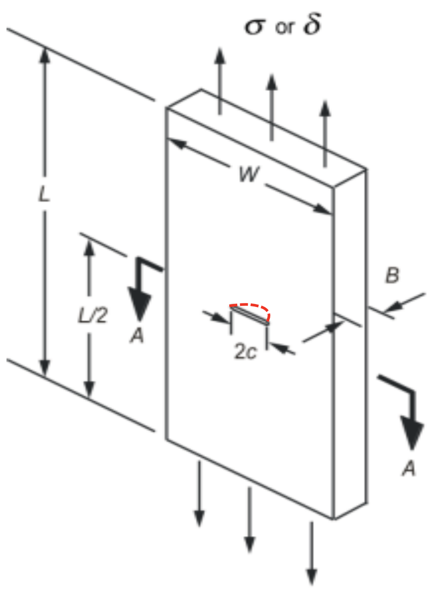
- Enrico Lucon – NIST
- Greg Thorwald – Quest Integrity Group
- Jason Bely – Alcoa
- Steven Altstadt – Stress Engineering Services
- Michael Windisch – MT Aerospace
- Ryan Sherman – Purdue University
- Francisco Martin – Purdue University
- Dawn Phillips – NASA MSFC

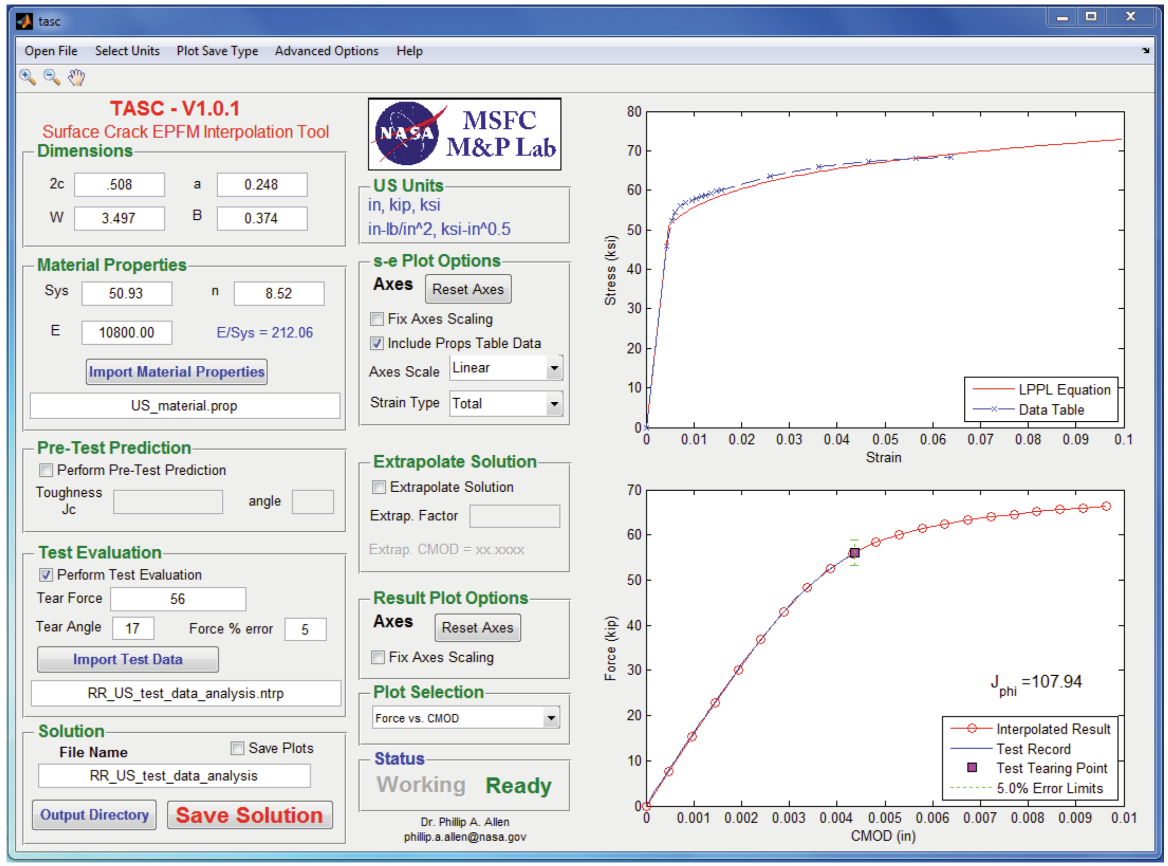
TASC Update

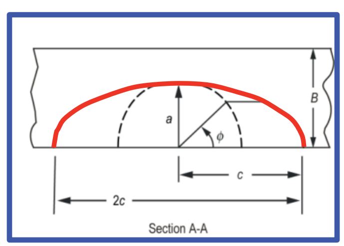
Damage Tolerance Assessment Branch
MSFC Engineering Directorate

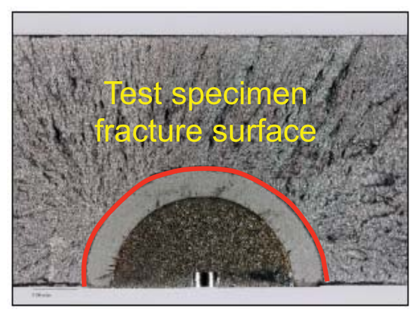
What is TASC?

- TASC (Tool for Analysis of Surface Cracks) is a computer program created by NASA MSFC that enables easy computation of three-dimensional, nonlinear *J*-integral (fracture energy) solutions for surface cracked plates in tension.









TASC Accessibility

- A TASC project page is hosted on Sourceforge.net at: https://sourceforge.net/projects/tascnasa/
- TASC can be freely downloaded in Windows® 64-bit standalone executable, Mac OS X® 64-bit standalone application, and MATLAB source file formats.
- No MATLAB license is required for the standalone executable versions license due to the royalty-free MATLAB Complier Runtime distribution provided with the program installation package, and no MATLAB experience is needed due to the simple GUI.
- TASC is released under the NASA Open Source Agreement Version 1.3.
- TASC was posted on Sourceforge on Jan. 28, 2014 and to date has had over 300 downloads
- TASC's background documentation:
  - Allen, P.A. and Wells, D.N., *Interpolation Methodology for Elastic-Plastic J-Integral Solutions for Surface Cracked Plates in Tension*, Engineering Fracture Mechanics 119, 2014, pp 173-201.
  - Allen, P.A. and Wells, D.N., *Applications of Automation Methods for Nonlinear Fracture Test Analysis, ASTM STP1571 on Sixth Symposium on Application of Automation Technology in Fatigue and Fracture Testing and Analysis*, Accepted for publication Nov. 2013.
  - Allen PA, Wells DN. *Elastic-Plastic J-Integral Solutions for Surface Cracks in Tension Using an Interpolation Methodology*. NASA MSFC; 2013. NASA/TM-2013-217480.